

WHAT IS CLAIMED IS:

1. An energy-trap thickness extensional vibration mode piezoelectric resonator, comprising:
a piezoelectric body including a plurality of piezoelectric layers and uniformly polarized in a thickness direction thereof; and
N number of internal electrodes, where N is an integer equal to 3 to 5, arranged in the piezoelectric body on top of each other with the piezoelectric layers disposed therebetween; wherein
the piezoelectric body vibrates in an $(N-1)$ th higher-order mode of a thickness extensional vibration mode generated by applying electric fields of opposite polarity alternately in the direction of thickness to piezoelectric layers between internal electrodes, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.50 \leq (D_1 + D_2)/2D \leq 1.00$ at $N = 3$, $0.50 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 4$, and $0.50 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.

2. An energy trap thickness extensional vibration mode piezoelectric resonator according to claim 1, wherein the N number of internal electrodes include substantially linear electrodes and intersect with each other through piezoelectric layers, and wherein the intersection portion constitutes an energy trap type piezoelectric vibration portion.

3. An energy-trap thickness extensional vibration mode piezoelectric resonator, comprising:

a piezoelectric body including a plurality of piezoelectric layers and uniformly polarized in a thickness direction thereof; and

N number of internal electrodes, where N is an integer equal to 3 to 5, arranged in the piezoelectric body on top of each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an $(N-1)$ th higher-order mode of a thickness extensional vibration mode generated by applying electric fields of opposite polarity alternately in the direction of thickness to piezoelectric layers between internal electrodes, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and

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the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.10 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 3$, $0.10 \leq (D_1 + D_2)/2D \leq 0.50$ at $N = 4$, and $0.10 \leq (D_1 + D_2)/2D \leq 0.45$ at $N = 5$.

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4. An energy trap thickness extensional vibration mode piezoelectric resonator according to claim 3, wherein the N number of internal electrodes include substantially linear electrodes and intersect with each other through piezoelectric layers, and wherein the intersection portion constitutes an energy trap type piezoelectric vibration portion.

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5. An energy-trap thickness extensional vibration mode piezoelectric resonator, the piezoelectric resonator comprising:

a piezoelectric body including a plurality of piezoelectric layers; and

N number of internal electrodes, wherein N is an integer equal to 3 to 5, disposed in the piezoelectric body and stacked on each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an $(N-1)$ th higher-

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order mode of a thickness extensional vibration mode and piezoelectric layers located between the internal electrodes are polarized in opposite direction alternately in the direction of thickness, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.60 \leq (D_1 + D_2)/2D \leq 1.10$ at $N = 3$, $0.65 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 4$, and $0.60 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.

6. An energy trap thickness extensional vibration mode piezoelectric resonator according to claim 5, wherein the N number of internal electrodes include substantially linear electrodes and intersect with each other through piezoelectric layers, and wherein the intersection portion constitutes an energy trap type piezoelectric vibration portion.

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7. An energy-trap thickness extensional vibration mode piezoelectric resonator, comprising:
a piezoelectric body including a plurality of piezoelectric layers; and

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N number of internal electrodes, wherein N is an integer equal to 3 to 5, disposed in the piezoelectric body and stacked on each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an $(N-1)$ th higher-order mode of a thickness extensional vibration mode and piezoelectric layers located between the internal electrodes are polarized in opposite direction alternately in the direction of thickness, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.10 \leq (D_1 + D_2)/2D \leq 1.10$ at $N = 3$, $0.10 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 4$, and $0.10 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.

8. An energy trap thickness extensional vibration mode piezoelectric resonator according to claim 7, wherein the N number of internal electrodes include substantially linear electrodes and intersect with each other through piezoelectric layers, and wherein the intersection portion constitutes an energy trap type piezoelectric vibration portion.

9. A ladder-type filter comprising
a series-arm resonator including a thickness
extensional vibration mode piezoelectric resonator according
to claim 1; and
a parallel-arm resonator.

10. A ladder-type filter comprising
a series-arm resonator including a thickness
extensional vibration mode piezoelectric resonator according
to claim 5; and
a parallel-arm resonator.

11. A ladder-type filter comprising
a parallel-arm resonator including a thickness
extensional vibration mode piezoelectric resonator according
to claim 3; and
a series-arm resonator.

12. A ladder-type filter comprising
a parallel-arm resonator including a thickness
extensional vibration mode piezoelectric resonator according
to claim 7; and

a series-arm resonator.

13. A piezoelectric resonator component comprising:
a thickness extensional vibration mode piezoelectric
resonator according to claim 1;
a case substrate bonded to the piezoelectric
resonator so as to define a space for allowing the
piezoelectric resonator to vibrate; and
a conductive cap bonded to the case substrate so as
to enclose the piezoelectric resonator.

14. A piezoelectric resonator component comprising:
a thickness extensional vibration mode piezoelectric
resonator according to claim 3;
a case substrate bonded to the piezoelectric
resonator so as to define a space for allowing the
piezoelectric resonator to vibrate; and
a conductive cap bonded to the case substrate so as
to enclose the piezoelectric resonator.

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14. A piezoelectric resonator component comprising:
a thickness extensional vibration mode piezoelectric
resonator according to claim 5;
a case substrate bonded to the piezoelectric
resonator so as to define a space for allowing the

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~~piezoelectric resonator to vibrate; and
a conductive cap bonded to the case substrate so as
to enclose the piezoelectric resonator.~~

16. A piezoelectric resonator component comprising:
a thickness extensional vibration mode piezoelectric
resonator according to claim 7;
~~a case substrate bonded to the piezoelectric
resonator so as to define a space for allowing the
piezoelectric resonator to vibrate; and
a conductive cap bonded to the case substrate so as
to enclose the piezoelectric resonator.~~